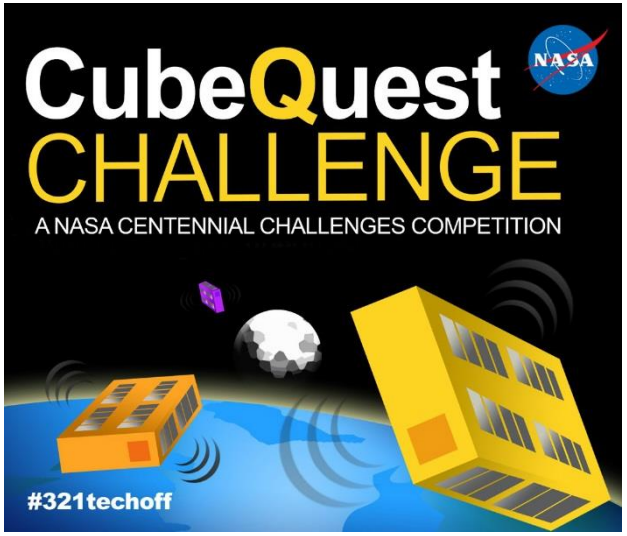
Cube Quest Kick-off: Communications Rules



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Topics

- Goals
- General Rules
- Specific Requirements

Goals

- The Cube Quest Challenge is designed to (1) encourage innovation in communications technology for small missions, (2) demonstrate operations in a new, challenging small satellite environment, and (3) demonstrate that data volumes and rates necessary to sustain useful science missions can be achieved.
- The amount of proscription was kept to a minimum to encourage the innovation.
- The rules are designed to maintain a level playing field for all Teams and to provide NASA with insight/oversight to minimize the potential for spoofing the Challenge.

General Rules

- Ground Tournaments are designed to give NASA insight into the design details and to make sure that the judges can evaluate the data blocks.
- NASA is not coordinating the licensing for RF transmission. Each Team must do that themselves for their satellite and, if required, their ground station.
  - The Ground Tournaments require submission of data packages using the EL-CID program to give uniformity in data presentation and help the Teams prepare their actual packages.
  - It is not too early to start coordinating with the FCC for any licensing needs. Document your application stages.
  - If the Team is using someone's ground station, include their licensing information in the Team data package.

General Rules

- NASA wishes to have awareness of the Challenge communications for verification purposes
  - Teams will need to inform NASA at least 24 hours in advance of when they are communicating as part of the Challenge so that NASA can listen in for verification purposes.
  - Routine mission operations or science operations do not require a notification to NASA.
  - NASA will also negotiate times to visit and observe operations and data collection to verify compliance.
  - NASA will not coordinate operational schedules to avoid mutual interference. The Teams will need to do this function in cooperation with their ground station operators.

NASA will perform monitoring to provide insight and verification

General Rules

- Document your design for
  - Forward Error Correcting code methodology if it is used. Note: FEC additional bits do not count for the data volume metric, only the uncoded bits count.
  - Specific details of the data transmission protocols and frame formats.

Document design details

Specific Requirements

- Frequency Allocation Packages
  - The Preliminary Frequency Allocation Data Package is basically the line diagram for EL-CID. Also include expected frequencies and data rates in addition to ground station locations.
  - Data Packages for Ground Tournaments are detailed updates to the EL-CID database as the design matures.
- Link Budgets
  - The Judges and SMEs reviewing the design need data to assess the viability of the forward and return links.
  - The Ground Tournament data package needs to include a detailed link budget for the command and telemetry links. This is for both RF and optical communications links.
  - An example link budget is shown on the next page. A similar computation is to be included in the documentation.

Documenting the link design

Specific Requirements

Example RF Link Budget; similar computation for optical links as well.

Purpose:	*Payload Link Budget*		Revision Date:	*12/17/2014*						
			Units	Notes:						
Transmitter (Tx) Source ID										
	Tx Power, W	2.5	Watts							
1	Tx Power, Pt	34.0	dBm							
2	Tx Component Line Losses, Ltl	0.5	dB							
3	Tx Antenna Gain (Peak), Gt	0.0	dBi	Assume:	Omnidirectional					
4	Tx Pointing Loss, Ltp	3.0	dB							
5	Tx Radome Loss, Ltr	0.0	dB							
6	EIRP (1-2+3-4-5)	30.5	dBm							
Propagation										
	Transmission Frequency, f	401.0	MHz							
	Link Range, R	20000.0	km							
	Propagation Factor, n	1.0								
7	Free Space Loss, Ls	170.5	dB							
8	Atmospheric Absorption, Lpa	0.0	dB							
9	Precipitation Absorption, Lpp	0.0	dB							
10	Total Propagation Loss (7+8+9)	170.5	dB							
Receiver (Rx) Sink ID										
11	Rx Antenna Gain (Peak), Gr	36.0	dBi							
12	Rx Polarization Loss, Lrpol	1.0	dB							
13	Rx Pointing Loss, Lrp	0.0	dB							
14	Rx Radome Loss, Lrr	0.0	dB							
15	Received effective carrier power (6-10+11-12-13-14)	-105.1	dBm							
16	Additional Receiver Chain Gain	2.4	dB							
17	Effective Carrier Power to Receiver (15+16)	-102.7	dBm							
18	Maximum Receiver Input Power	-85	dBm							
19	High Receiver Input Margin (18-17)	17.7	dB							
20	Minimum Receiver Input Power	-125.0	dBm							
21	Low Receiver Input Margin (17-20)	22.3	dB							
Noise				**Noise Bandwidth Determination**			**Rx Noise Figure Determination**			
22	Standard Thermal Noise, kT	-174.0	dBm/Hz	**NTIA Necessary**			**(at input to receiver)**			
23	Rx Noise Bandwidth, W	40.1	dBHz	**Bandwidth:**	8256	Hz	**G/T**	4.7	dB/K	
24	Rx Noise Figure, NF	9.5	dB	**Expansion**	125%					
25	Effective Noise Power (22+23+24)	-124.3	dBm	**System**			**Tsys**	33.7	dBK	
				Bandwidth:	10320	Hz	**NF**	9.5	dB	
Result										
26	Received CNR (17-25)	21.6	dB							
27	Implementation Loss	3.0	dB	Assumed value						
28	Available CNR (26-27)	18.6	dB							
29	Uncoded Baseband Data Rate	9600	bps							
	Modulation Type (select)	GMSK		**Note:** check NTIA assumed system parameters on *Background* tab						
	Modulation Order (M)	2								
30	$\log_2(M)$	1								
31	Coding Rate (k/n)	1.000		Assume:	No coding					
32	Coded Baseband Data Rate (29/31)	9600	bps							
	Modulation Symbol Rate, Rs	9600	sps							
33	Modulation Symbol Rate, Rs [32/30]	39.8	dBsps							
34	Received Es/No (28+23-33)	19.0	dB		Setting up Required Eb/No solver Information					
35	Received Eb/No (34-[30]-[31])	19.0	dB		BER(Eb/No)	0.000025	Eb/No	15.00		
36	Desired BER	0.000010								
37	Required Eb/No	15.0	dB	Run Solver to Generate the Required Eb/No for this modulation						
38	Margin (35-37)	4.0	dB	type and desired BER						

Example Link Budget

Specific Requirements

- Random data generation is to be accomplished via:
  1. NASA assigns the Team with a unique competition key that is 256 bits in length. The Team will use this key in generating the random data and include the key in the header of the transmitted data packet containing Challenge random data.
  2. Data blocks are defined as 1024-bit units (128 octets). Multiple data blocks can be generated consecutively and stored in the transmission packet. The maximum number of data blocks in a single transmission packet is left for the Team to determine based on data protocol constraints, coding efficiency, and operational constraints. Only complete blocks will be counted in Challenge scoring.

Specific Requirements

- Random data generation is to be accomplished via:
  3. The spacecraft time for each data packet that is generated is to be used with the Team-unique key to generate the random block sequence. This time is to be included in the transmission packet header with the Challenge data. The time is to be encoded as an ASCII string in YYYYMMDDHHMMSS.S format. There is no requirement to slave this time to UTC but it should be approximately correct to within an offset of less than one hour.
  4. The random data shall be generated from a linear congruent generator using the algorithm

$$x_n = (ax_{n-1} + b)\ mod\ M$$

where x_0 is the seed value computed from the Team key and the generation time.

Specific Requirements

- Random data generation is to be accomplished via:
  5. The values for *a*, *b*, and *M* shall be
     a) 1664525 = *a*
     b) 1013904223 = *b*
     c) 2^{32} = *M*
  6. The seed value shall be computed by
     a) Concatenating the Team key with the spacecraft time to form a 384-bit string.
     b) This 384-bit string is to be divided into 32-bit segments.
     c) The 32-bit segments are bitwise XORed to form a 32-bit seed value.

Specific Requirements

- The recommended data transmission packet is based on the CCSDS 133-B-1 recommended standard.

Attached Synch Marker	Packet Primary Header							Packet Data Field		
	Version No.	Packet Identification			Packet Sequence Control		Packet Data Length	Packet Secondary Header		Competition Data Block
		Type Indicator	Packet Secondary Header Flag	Application Process Identifier	Sequence Flags	Packet Sequence Count		Spacecraft Time Stamp UTC as YYYYMMDDHHMMSS.S	Team-unique Competition Key	
32 bits	3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits	128 bits	256 bits	User Determined Length

Specific Requirements

- Each team shall supply a CubeSat communications log to the judges to verify competition timing. This log shall contain this minimum set of data:
  - UTC time and date for the beginning of the operating period
  - UTC time and date for acquisition of signal
  - Total time of acquired signal (seconds)
  - UTC time and date for the loss of signal/end of operating period
  - Rest carrier frequency
  - Beginning and ending Doppler offsets at a minimum; intermediate values taken at least once per five minute period are preferred
  - Data Rate
  - Link Quality (BER, C/N, etc.) estimate
  - Total data received when in receiver lock
  - Azimuth and Elevation pointing data during the operational period
- Each Team shall also supply a raw data archive.